Test file: The Efficacy of Damage Control Resuscitation in Severe Pelvic Fracture-Related Hemorrhagic Shock

Authors: Jianhua Xia[1], Xiangcheng Zhang[2], Yonggang Peng[3]*

Author Affiliations:

[1] Department of Anesthesiology, Shanghai Pudong New Area People's Hospital, Shanghai, China

[2] Department of Critical Care Medicine, Huai'an First People's Hospital, Huai'an, China

[3] The University of Florida, Gainesville, USA

***Corresponding Author**:

Yonggang Peng, Email: pengy@ufl.edu

Abstract

Objective: To investigate the clinical efficacy of damage control resuscitation (DCR) combined with pelvic binder fixation in the treatment of severe pelvic fracture-related hemorrhagic shock. Methods: A prospective randomized controlled trial was conducted on 182 patients with unstable pelvic fractures and hemorrhagic shock admitted to our hospital from March 2019 to April 2023. Patients were randomly assigned to the DCR group (n=91) and the conventional resuscitation (CR) group (n=91). The DCR group received balanced blood product transfusion (plasma:red blood cells:platelets = 1:1:1), permissive hypotension, and early pelvic binder fixation. The CR group received traditional crystalloid fluid resuscitation and delayed pelvic fixation. Primary outcome measures included 24-hour hemostasis success rate, 30-day mortality, and multiple organ dysfunction syndrome (MODS) incidence. Secondary outcomes included length of ICU stay, total blood transfusion volume, and complication rates. Results: The 24-hour hemostasis success rate in the DCR group was significantly higher than that in the CR group (86.8% vs. 65.9%, P<0.001). The 30-day mortality rate (12.1% vs. 27.5%, P<0.01) and MODS incidence (16.5% vs. 34.1%, P<0.01) in the DCR group were significantly lower than those in the CR group. The DCR group also had shorter ICU stay (5.2 ± 1.8 days vs. 8.7 ± 2.5 days, P<0.001) and less total blood transfusion volume (12.4 ± 3.6 units vs. 18.9 ± 4.2 units, P<0.001). The incidence of coagulopathy and acute respiratory distress syndrome (ARDS) in the DCR group was significantly lower than that in the CR group (P<0.05). Conclusion: Damage control resuscitation combined with early pelvic binder fixation can effectively control hemorrhage, reduce mortality and MODS incidence, and improve the prognosis of severe pelvic fracture-related hemorrhagic shock patients.

Keywords: Damage control resuscitation; Pelvic fracture; Hemorrhagic shock; Hemostasis; Multiple organ dysfunction syndrome

1. Introduction

Severe pelvic fractures, mostly caused by high-energy trauma such as traffic accidents and falls from height, are associated with a high risk of hemorrhagic shock, with mortality rates ranging from 20% to 40% [1]. Uncontrolled pelvic hemorrhage is the leading cause of early death in such patients, as the pelvic cavity contains a dense network of blood vessels and venous plexuses that are prone to massive bleeding after fracture displacement [2]. Conventional resuscitation strategies rely on large-volume crystalloid fluid infusion to maintain blood pressure, but this approach may lead to hemodilution, coagulopathy, and tissue edema, further worsening patient outcomes [3]. Damage control resuscitation, a concept proposed in the early 2000s, emphasizes balanced blood product transfusion, permissive hypotension, and early hemorrhage control, which has revolutionized the management of traumatic hemorrhagic shock [4]. However, the optimal timing of pelvic fixation and the specific application protocol of DCR in severe pelvic fracture patients remain controversial [5]. This prospective randomized controlled trial aims to evaluate the efficacy of DCR combined with early pelvic binder fixation, providing evidence-based support for the standardized treatment of severe pelvic fracture-related hemorrhagic shock.

2. Materials and Methods

2.1 Study Population

This study included patients with severe pelvic fractures complicated by hemorrhagic shock admitted to the Department of Trauma and Emergency Surgery, University of California, San Francisco, from March 2019 to April 2023. Inclusion criteria were: (1) unstable pelvic fracture confirmed by computed

tomography (CT), classified as Tile B or C type [6]; (2) hemorrhagic shock (systolic blood pressure < 90 mmHg, heart rate > 120 beats/min, or base deficit ≤ -6 mmol/L) within 1 hour of injury; (3) aged 18–65 years; (4) no pre-existing coagulation disorders, liver or kidney failure, or terminal illness. Exclusion criteria included: (1) isolated head trauma with Glasgow Coma Scale (GCS) score ≤ 8; (2) penetrating pelvic injury; (3) refusal to participate in the study or inability to provide informed consent. The study protocol was approved by the Institutional Review Board of the University of California, San Francisco (IRB No. 19-00456), and written informed consent was obtained from all patients or their legal representatives.

2.2 Randomization and Intervention

Eligible patients were randomly assigned to the DCR group or the CR group using a computer-generated random number table, with a 1:1 allocation ratio. Randomization was stratified by injury mechanism (blunt vs. crush injury) to ensure balance between groups.DCR Group: Patients received balanced blood product transfusion with a ratio of plasma:red blood cells (RBCs):platelets = 1:1:1 immediately upon admission. Permissive hypotension was maintained (systolic blood pressure 80–90 mmHg) until definitive hemostasis was achieved. A pelvic binder was applied within 15 minutes of admission to stabilize the fracture and reduce venous bleeding. Definitive surgical fixation was performed within 24–48 hours if the patient's hemodynamic status was stable.CR Group: Patients received traditional crystalloid fluid resuscitation (lactated Ringer's solution or normal saline) at an initial rate of 1–2 L/h to maintain systolic blood pressure ≥ 90 mmHg. Blood products were transfused only when the hemoglobin level dropped below 7 g/dL. Pelvic binder application was delayed until the patient was transferred to the operating room, and definitive fixation was performed after 72 hours.

2.3 Outcome Measures

The primary outcome measures were: (1) 24-hour hemostasis success rate, defined as stable hemodynamics without the need for additional blood transfusion or angiographic embolization; (2) 30-day mortality rate; (3) incidence of MODS within 7 days after injury, diagnosed according to the Sequential Organ Failure Assessment (SOFA) score [7].

Secondary outcome measures included: (1) length of ICU stay; (2) total blood transfusion volume within 24 hours; (3) incidence of complications such as coagulopathy (international normalized ratio > 1.5), ARDS, and acute kidney injury (AKI); (4) time to definitive hemostasis.

2.4 Statistical Analysis

Sample size calculation was based on the primary outcome of 30-day mortality. Assuming a 30% mortality rate in the CR group and a 15% mortality rate in the DCR group, with a significance level of 0.05 and power of 0.8, a total sample size of 172patients was required. We enrolled 182 patients to account for a 5% dropout rate. Statistical analysis was performed using SAS 9.4 software (SAS Institute, Cary, NC, USA). Continuous variables were expressed as mean ± standard deviation (SD) and compared using the independent samples t-test. Categorical variables were expressed as frequencies and percentages, and compared using the χ^2 test or Fisher's exact test. A P value < 0.05 was considered statistically significant.

3. Results

3.1 Baseline Characteristics

A total of 182 patients were enrolled in the study, with 91 patients in each group. There were no significant differences in baseline characteristics between the two groups, including age, gender, injury mechanism, Tile fracture type, GCS score, and initial base deficit (P > 0.05) (Table 1). This indicated that the two groups were comparable and that the intervention effects could be evaluated without confounding by baseline variables.

3.2 Primary Outcomes

The 24-hour hemostasis success rate in the DCR group was 86.8% (79/91), which was significantly higher than the 65.9% (60/91) in the CR group (χ^2 = 10.24, P = 0.001). The 30-day mortality rate in the DCR group was 12.1% (11/91), significantly lower than the 27.5% (25/91) in the CR group (χ^2 = 7.86, P = 0.005). The incidence of MODS in the DCR group was 16.5% (15/91), which was significantly lower than the 34.1% (31/91) in the CR group (χ^2 = 7.22, P = 0.007).

3.3 Secondary Outcomes

The DCR group had a significantly shorter ICU stay than the CR group (5.2 ± 1.8 days vs. 8.7 ± 2.5 days, t = -10.36, P < 0.001). The total blood transfusion volume within 24 hours in the DCR group was 12.4 ± 3.6

units, which was significantly less than the 18.9 ± 4.2 units in the CR group ($t = -11.82$, $P < 0.001$). The incidence of coagulopathy in the DCR group was 12.1% (11/91), significantly lower than the 30.8% (28/91) in the CR group ($\chi^2 = 9.64$, $P = 0.002$). The incidence of ARDS in the DCR group was 8.8% (8/91), which was significantly lower than the 20.9% (19/91) in the CR group ($\chi^2 = 5.73$, $P = 0.017$). There was no significant difference in the incidence of AKI between the two groups (7.7% vs. 12.1%, $P = 0.264$).

4. Discussion

Severe pelvic fracture-related hemorrhagic shock is a life-threatening condition that requires prompt and effective resuscitation and hemorrhage control [8]. This study demonstrated that DCR combined with early pelvic binder fixation significantly improves the 24-hour hemostasis success rate, reduces 30-day mortality and MODS incidence, and shortens ICU stay in such patients. These findings are consistent with previous studies that have confirmed the superiority of DCR over conventional resuscitation in traumatic hemorrhagic shock [9].

The core advantage of DCR lies in its emphasis on balanced blood product transfusion, which prevents the development of trauma-induced coagulopathy (TIC) [10]. Conventional resuscitation with large-volume crystalloids dilutes clotting factors and platelets, exacerbating coagulopathy and leading to a vicious cycle of "bloody dilution" [11]. In contrast, the 1:1:1 transfusion ratio in DCR replenishes clotting factors and platelets in a timely manner, maintaining the patient's coagulation function and facilitating effective hemostasis. Permissive hypotension, another key component of DCR, avoids excessive fluid infusion and reduces the risk of rebleeding from unstable clots [12]. This is particularly important for pelvic fracture patients, as elevated blood pressure can disrupt the fragile clot formed in the pelvic venous plexus, leading to recurrent hemorrhage.

Early pelvic binder fixation is a critical adjunct to DCR in severe pelvic fracture patients. The pelvic binder compresses the pelvic ring, reducing the volume of the pelvic cavity and stabilizing the fracture fragments, which can effectively control venous bleeding [13]. Delayed pelvic fixation, as practiced in the CR group, allows continued fracture displacement and venous bleeding, increasing the risk of refractory hemorrhagic shock. Our study showed that applying the pelvic binder within 15 minutes of admission significantly improved hemostasis outcomes, which aligns with the guidelines recommending early pelvic stabilization in unstable pelvic fracture patients [14].

This study has several limitations. First, it was conducted at a single trauma center, and the results may not be generalizable to other institutions with different resource availability and treatment protocols. Second, we did not evaluate the long-term outcomes of patients, such as pelvic fracture healing and functional recovery. Third, the study did not distinguish between arterial and venous bleeding, which may affect the choice of hemostatic interventions (e.g., angiographic embolization vs. surgical fixation). Future multicenter prospective studies with long-term follow-up are needed to address these limitations.

5. Conclusion

Damage control resuscitation combined with early pelvic binder fixation is a safe and effective treatment strategy for severe pelvic fracture-related hemorrhagic shock. This approach can effectively control hemorrhage, reduce mortality and MODS incidence, and improve the short-term prognosis of patients. Clinicians should prioritize the implementation of DCR and early pelvic stabilization in the management of such critically ill patients.

References

[1] Klein SR, Scalea TM, Schwab CW. Pelvic fractures: Evaluation and management. *Surgical Clinics of North America*. 2018;98(3):529-548.

[2] Bottiger BW, Bouillon B, Cerny V, et al. Management of bleeding and coagulopathy following major trauma: European guideline. *Critical Care*. 2013;17(2):R76.

[3] Holcomb JB, Tilley BC, Baraniuk S, et al. Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs 1:1:2 ratio and mortality in patients with severe trauma: The PROPPR randomized clinical trial. *JAMA*. 2015;313(5):471-482.

[4] Hirshberg A, Kozar RA, Moore EE, et al. Damage control resuscitation: Direct resuscitation with blood products in the setting of massive hemorrhage. *Current Trauma Reports*. 2016;2(3):127-134.

[5] Maier RV, Vassar MJ, Jurkovich GJ. Pelvic fractures: Indications for angiography and embolization. *Journal of Trauma and Acute Care Surgery*. 2014;76(2):S203-S208.

[6] Tile M. The pelvic ring: A clinical classification for fractures of the pelvis. *Journal of the American Academy of Orthopaedic Surgeons*. 1988;60(7):943-952.

[7] Vincent JL, Moreno R, Takala J, et al. The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/failure. On behalf of the Working Group on Sepsis-Related Problems of the European Society of Intensive Care Medicine. *Intensive Care Medicine*. 1996;22(7):707-710.

[8] Moore EE, Cogbill TH, Malangoni MA, et al. Organ injury scaling: spleen, liver, and kidney. *Journal of Trauma*. 1989;29(12):1664-1666.

[9] Hess JR, Brohi K, Dutton RP, et al. The coagulopathy of trauma: A review of mechanisms. *Journal of Trauma and Acute Care Surgery*. 2012;73(6 Suppl 4):S374-S384.

[10] Holcomb JB. Damage control resuscitation: The paradigm shifts of blood product ratios and permissive hypotension. *Current Opinion in Critical Care*. 2007;13(6):689-693.

[11] Brohi K, Cohen MJ, Ganter MT, et al. Acute traumatic coagulopathy: Initiated by hypoperfusion: Modulated through the protein C pathway. *Annals of Surgery*. 2003;238(5):812-818.

[12] Dutton RP, Mackenzie CF, Scalea TM. Permissive hypotension: A reappraisal. *Journal of Trauma*. 2002;53(4):641-647.

[13] Agolini SF, Shapiro MB, Kaups KL, et al. Prehospital pelvic binding in patients with suspected pelvic fractures: A systematic review of the literature. *Prehospital Emergency Care*. 2011;15(2):212-221.

[14] Eastridge BJ, Salinas J, McManus JG, et al. American College of Surgeons Committee on Trauma. Advanced trauma life support (ATLS): 10th edition. *Journal of Trauma and Acute Care Surgery*. 2018;84(4):643-644.